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ABSTRACT

The ue of hands-on models in teaching protein synthesis, in comparison to traditional expository methods, has been shown to improve the content achievement of biology students. The purpose of this study was to evaluate a set of models and the accompanying laboratory exercises in terms of content achievement and attitude toward biology and biochemistry. Discussion includes procedures, subject, data collection, and the findings of the study. Appendices include the pre-test and follow-up test, post-test and semantic differentials used to evaluate biology and biochemistry attitudes. It was found that attitudes toward biology and biochemistry among the students in the sample were significantly higher among model-using students, but the content achievement of model-using students was not significantly different from students not using models. (CW)

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A STUDY OF THE EFFECTS OF LARGE HANDS-ON PROTEIN SYNTHESIS MODELS ON THE BIOLOGY ACHIEVEMENT AND ATTITUDES TOWARDS BIOLOGY OF STUDENTS

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A STUDY OF THE EFFECTS OF LARGE HANDS-ON PROTEIN SYNTHESIS MODELS ON THE BIOLOGY ACHIEVEMENT AND ATTITUDES TOWARDS BIOLOGY OF STUDENTS

In a world where genetic engineering and molecular biology are becoming ever more important, the development of a thorough understanding of protein synthesis is a vital part of basic biology instruction. Teaching this highly abstract concept to students, many of whom have not yet reached formal reasoning (Renner, Stafford, Lawson, McKinnon, Friot and Kellogg, 1976, Chapter 6), is made more difficult by the lack of good "hands-on" instructional aids.

Most of the currently available models of DNA, RNA and amino acids are either too expensive, too fragile or too small for routine student laboratory use. To understand protein synthesis and its manipulation in genetic engineering, students must fully understand the roles played by DNA, messenger RNA, transfer RNA and ribosomes, as well as the chemical nature of amino acids.

While taking a course in molecular genetics in 1985, the first author designed a set of large and durable models that students can manipulate while studying protein synthesis. The models were constructed from locally available materials and included all of the structural and functional features of DNA, mRNA, tRNA, ribosomes and the 21 amino acids in the alpha chain of human insulin. In two accompanying laboratory exercises, also developed by the first author, the students play the roles of the enzymes

that control the coding and assembly phases of protein synthesis.

Purpose

The purpose of this study was to evaluate the as yet untested effectiveness of the set of models and the two accompanying protein synthesis laboratory exercises with a series of two lectures on protein synthesis with high school biology students. The study was guided by two research questions:

1. To what degree do the models and laboratory exercises effect the content achievement of the students?
2. To what degree do the models and laboratory exercises effect the attitudes of the students towards biology and towards biochemistry?

Null hypotheses were stated that proposed applications of the large hands-on models, lab exercises and accompanying lectures would not result in higher content achievement, and more positive attitudes towards biology and towards biochemistry.

Procedures

Treatments

In this study the experimental group received four class periods of instruction. These included: 1) a one period lecture on the structure and function of DNA and RNA.

2) a one period lab in which the students constructed the DNA and mRNA that would code for two amino acids using the large hands-on models, 3) a one period lecture on protein synthesis, and 4) a one period lab that also involved the large hands-on models wherein students played the role of the enzymes that control the synthesis of the 21 amino acids in the short chain of human insulin.*

The control group received the same two periods of lecture on days one and two, and an enviornmental science exercise on days three and four. The two days of lecture on protein synthesis represented the way biology teachers traditionally deal with the topic of protein synthesis.

Subjects

The subjects were 28 ninth grade academic biology students in two of the first author's biology classes at Port Allegany High School in Pennsylvania. The students had been randomly assigned to the two sections of biology by the school's scheduling computer. There were 14 students (6 boys and 8 girls) in the experimental group (class) and 14 students (6 boys and 8 girls) in the control group (class).

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* Individuals interested in the models and laboratory exercises are welcome to write to the first author for information.

During the course of the experiment 4 students from the experimental group and 3 students from the control group were absent one or more times. Data from these students were not used in tabulating the results. Hence, the actual size of the experimental group was 10 students and the control group was 11 students.

Instruments

A content achievement test and two attitude instruments developed by the first author were used to collect data on the research questions. Two equivalent forms of the content achievement test were developed. Each was made up of 13 multiple choice (5 choices) questions that covered the 10 instructional objectives of the four lessons in the treatments. The content validity of the two forms and their equivalence was checked by three other science teachers against the instructional objectives. In scoring the content tests, one point was given for each correct answer. Hence, content achievement test scores could range from 0 to 13. A copy of the tests appears in Appendix A.

The attitude instruments were semantic differential scales using 10 pairs of polar adjectives. The adjective pairs were selected by the members of a biology class not involved in the study. The class members rated the relevance of 13 "evaluative" pairs of adjectives to "biology" and "biochemistry" that had been selected by the authors from ones used and validated by Osgood, Scici and

Tannenbaum (1957). Ten adjective pairs were selected for use on the attitude instruments. Scores on each attitude instrument could range from 1 to 7 with 7 representing the most positive attitude. A copy of these instruments appears in Appendix B.

Data Collection

Both groups of subjects were pretested with the content achievement and two attitude instruments the day before the first treatment period, posttested with them on the day following the fourth treatment period for the experimental group, and given follow-up tests with the instruments six weeks after the experiment ended. The same form of the content achievement test was used for the pretest and follow-up test, and the second form for the posttest.

This research design is known to as the Pretest Posttest Control Group Design (Campbell and Stanley, 1966), a true experimental design with both high internal and external validity. Kirk (1968) classifies to the design statistically as being of the split-plot factorial type and recommends repeated measures analysis of variance. This analysis was completed on the data for each of the three dependent variables using the SPSS MANOVA Program (Hull and Nie, 1981). Tukey's Honest Significant Difference (HSD) Test was used for post-hoc analysis.

Findings

The means and standard deviations for the sets of test data on the three instruments/variables are presented in Table I.

Insert Table I about here

The repeated measures ANOVA tables for content achievement, attitudes towards biology and attitudes towards biochemistry are presented as Table II through IV, respectively. The treatment effect was not found to be statistically significant on any of the three variables. The assessment effect was found to be statistically significant on content achievement (.001 level) and attitudes towards biology (.05 level). A statistically significant interaction between treatment and assessment was found on attitudes towards biology and attitudes towards biochemistry (both at the .05 level).

Insert Tables II through IV about here

Tables V through VII show the mean differences on the respective variables and note which differences were found to be statistically significant at the .05, .01 and .001 levels upon application of Tukey's HSD Test. Of interest on content achievement are significant pretest to posttest

increases in the experimental group (.01 level) and in the control group (.01 level). The attitudes towards biology of the control group dropped significantly from pretest to follow-up test (.001 level), while the experimental group showed significantly more positive attitudes towards biology on the posttest (.01 level) and follow-up test (.001) than did the control group. Also, the experimental group showed significantly more positive attitudes towards biochemistry on the posttest than the control group did on the pretest (.01 level), posttest (.001 level) and follow-up test (.01 level).

Insert Tables V through VII about here

Based upon these findings the null hypotheses for attitudes towards biology and towards biochemistry were rejected, while that on content achievement was not.

Discussion

Use of the large hands-on models in teaching protein synthesis significantly improved the content achievement of the students as did the control treatment, the expository way biology teachers traditionally deal with protein synthesis. Notwithstanding, the experimental group showed more positive attitudes towards biology and towards biochemistry on the posttest and/or follow-up test. Hence,

the two treatments appear to be equivalent as far as content achievement is concerned, but use of the large hands-on models in teaching protein synthesis resulted in more positive attitudes. Given the importance of attitudes in teaching and learning (Koballa and Crawley, 1985) these findings justify use of large hands-on models that students manipulate during high school biology instruction on protein synthesis.

What possible explanation exists for the lack of difference between the two treatments on content achievement? In retrospect the authors believe the content achievement test suffered from a ceiling effect. That is, the multiple-choice questions on the content tests did not measure the depth of understanding of protein synthesis gained by the students in the experimental group.

To test this inference, each group of students was given an optional extra credit essay question on the process of protein synthesis on the course semester examination. In the experimental group all students attempted to answer the question and the majority gave detailed descriptions of protein synthesis that went far beyond the information requested by the content achievement test items. By comparison, nearly half of the control group did not answer the extra credit question and those who did gave little detail of the protein synthesis process. Use of short answer essay items on the content achievement tests might

have made those instruments more sensative to differences in subjects' understanding of protein synthesis. Concept maps (Novak and Gowin, 1984) also could have been used to assess students' depth of understanding of the protein synthesis process.

While the results of this study are encouraging, a better understanding of the value of large hands-on models that students manipulate during instruction on biochemical processes will require studies that cover a wider range of topics (e.g., respiration and photosynthesis), use higher level items to assess content achievement, and involve larger samples of students.

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Appendix A

Code _____

Date _____

Pretest and Follow-up Test -- Chapter 8

In the space provided, place the letter of the term that best completes each of the following statements.

_____ 1. A protein molecule is made up of many smaller units called: A. sugars, B. fatty acids, C. phosphates, D. amino acids, E. none of these.

_____ 2. The units of a protein molecule are joined together by special bonds called --- bonds. A. peptide, B. ionic, C. covalent, D. hydrogen, E. none of these.

_____ 3. DNA controls the production of --- in the cell. A. proteins, B. fats, C. carbohydrates, D. starches, E. none of these.

_____ 4. The sugar group in DNA is ---. A. ribose, B. a disaccharide, C. a phosphate, D. deoxyribose. E. none of these.

_____ 5. In the replication of a DNA molecule, cytosine always bonds with ---. A. thymine, B. guanine, C. uracil, D. adenine, E. none of these.

_____ 6. Which of the following <u>is not</u> a difference between DNA and RNA? A. the sugar groups are slightly different, B. DNA has two strands, RNA only one, C. DNA phosphate has less oxygen, D. uracil is substituted for thymine in RNA. E. none of these.

_____ 7. Transfer RNA is responsible for the movement of --- in protein synthesis. A. sugars, B. fatty acids, C. amino acids, D. phosphates, E. none of these.

_____ 8. Messenger RNA carries the --- in protein synthesis. A. genetic code, B. amino acids, C. sugars, D. phosphate, E. none of these.

_____ 9. The ribosome contains a special form of --- and protein which translate the genetic message. A. DNA, B. RNA, C. fat, D. sugar, E. none of these.

_____ 10. During transcription, a molecule of --- is formed on the split DNA molecule. A. transfer RNA, B. messenger RNA, C. ribosomal RNA, D. amino acid, E. none of these.

_____ 11. The nitrogen bases in DNA must be --- for the genetic code to produce the right protein. A. at the right pH, B. at the right temperature, C. in the proper sequence, D. all the same size, E. none of these.

_____ 12. The --- on a mRNA molecule carries the transcribed message for a single amino acid. A. codon, B. anticodon, C. ribosome, D. antibody, E. none of these.

_____ 13. The synthesis of protein takes place on the cell's ---. A. cytoplasm, B. cell wall, C. nucleus, D. lysosome, E. none of these.

Appendix A (continued)

Code _____

Date _____

Posttest -- Chapter 8

In the space provided, place the letter of the term that best completes each of the following statements.

_____ 1. The units that make up protein molecules are called: A. fatty acids, B. sugars, C. nucleic acids, D. phosphates, E. none of these.

_____ 2. Peptide bonds join --- together to make proteins. A. fats, B. sugars, C. nucleotides, D. amino acids, E. none of these.

_____ 3. The production of protein in the cell is controlled by ---. A. DNA, B. amino acids, C. fats, D. carbohydrates, E. none of these.

_____ 4. Deoxyribose is the --- group in DNA. A. phosphate, B. base, C. sugar, D. fatty acid, E. none of these.

_____ 5. In the replication of a DNA molecule, thymine always bonds with ---. A. cytosine, B. adenine, C. uracil, D. guanine, E. none of these.

_____ 6. Which of the following <u>is not</u> a difference between DNA and RNA? A. the sugar groups are slightly different, B. DNA has two strands, RNA only one, C. only RNA is found in a variety of structural forms, D. uracil is substituted for thymine in RNA. E. none of these.

_____ 7. Amino acids are moved to the ribosome by ---. A. tRNA, B. mRNA, C. rRNA, D. DNA, E. none of these.

_____ 8. In protein synthesis, the genetic code is built into the --- molecule. A. tRNA, B. mRNA, C. rRNA, D. DNA, E. none of these.

_____ 9. Translation of the genetic message takes place on the --- which is made up of special RNA and protein. A. nucleus, B. codon, C. ribosome, D. nucleotide, E. none of these.

_____ 10. A molecule of messenger RNA is formed during ---. A. translation, B. transcription, C. protein synthesis, D. transportation, E. none of these.

_____ 11. The genetic code of an organism is determined by the sequence of the --- in the organism's DNA. A. phosphates, B. sugars, C. lipids, D. nitrogen bases, E. none of these.

_____ 12. The codon on a mRNA molecule matches the --- on the tRNA molecule. A. anticodon, B. antibody, C. phosphate, D. ribose sugar, E. none of these.

_____ 13. The cell's --- reads the genetic code on the mRNA molecule to begin protein synthesis. A. nucleus, B. DNA, C. tRNA, D. cell wall, E. none of these.

Appendix B

Code _____

Date _____

Each of the pairs of words below describes an attitude or feeling you may have towards Biology. Place an X in the space that best represents your feeling. For example if you feel strongly about a word place the X in the space next to the word. If you have no feeling towards either word, place your X in the center space. When you have finished the Biology scale, please complete the scale for Biochemistry. Remember that your feelings may be different for the two subjects.

Biology

positive____,____,____,____,____,____,____negative
messy____,____,____,____,____,____,____clean
unimportant____,____,____,____,____,____,____important
interesting____,____,____,____,____,____,____boring
hard____,____,____,____,____,____,____easy
simple____,____,____,____,____,____,____complicated
unnecessary____,____,____,____,____,____,____necessary
clear____,____,____,____,____,____,____confusing
fun____,____,____,____,____,____,____work

Biochemistry

positive____,____,____,____,____,____,____negative
messy____,____,____,____,____,____,____clean
unimportant____,____,____,____,____,____,____important
interesting____,____,____,____,____,____,____boring
hard____,____,____,____,____,____,____easy
simple____,____,____,____,____,____,____complicated
unnecessary____,____,____,____,____,____,____necessary
clear____,____,____,____,____,____,____confusing
fun____,____,____,____,____,____,____work

Table I

Means and Standard Deviations on Content Achievement and Attitude Data

Group	n	Content Achievement		Attitudes Towards Biology		Attitudes Towards Biochemistry	
		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Experimental	10						
Pretest		4.10	2.13	4.40	0.91	3.69	1.49
Posttest		7.90	4.07	4.36	1.12	4.26	1.47
Follow-Up		6.20	1.69	4.35	1.31	3.62	1.22
Control	11						
Pretest		4.91	1.58	4.01	0.94	3.11	0.91
Posttest		7.91	2.02	3.62	0.76	2.99	0.85
Follow-Up		6.36	1.50	3.19	1.00	3.18	0.96

Table II

Repeated Measures Analysis of Variance on Content Achievement

Source	SS	df	MS	F	p
Between Subjects					
A (Treatments)	15.52	1	15.52	2.51	.130
Subjects w. gps.	117.75	19	117.75		
Within Subjects					
B (Assessments)	66.13	2	33.06	9.50	.000
AB (Interaction)	9.19	2	4.59	1.31	.190
B X Subj. w. gps.	139.21	40	3.48		

Table III

Repeated Measures Analysis of Variance on Attitudes Towards Biology

Source	SS	df	MS	F	p
Between Subjects					
A (Treatments)	8.88	1	8.88	3.45	.079
Subjects w. gps.	48.87	19	2.57		
Within Subjects					
B (Assessments)	2.33	2	1.17	3.99	.026
AB (Interaction)	1.70	2	0.85	2.93	.040
B X Subj. w. gps.	11.71	40	0.29		

Table IV

Repeated Measures Analysis of Variance on Attitudes Towards Biochemistry

Source	SS	df	MS	F	p
Between Subjects					
A (Treatments)	9.14	1	9.14	2.88	.106
Subjects w. gps.	60.27	19	3.17		
Within Subjects					
B (Assessments)	0.60	2	0.30	0.62	.542
AB (Interaction)	2.07	2	1.45	3.02	.034
B X Subj. w. gps.	19.31	40	0.48		

Table V

Tukey's HSD Test on Content Achievement Mean Differences

	Experimental			Control		
	Pre	Post	F. Up	Pre	Post	F. Up
Experimental						
Pre		3.80**	2.10	0.81	3.81***	2.26*
Post			1.70	2.99**	0.01	1.54
F. Up				1.29	1.71	0.16
Control						
Pre					3.00**	1.45
Post						1.55
F. Up						

* $p<0.05$; ** $p<0.01$; *** $p<0.001$

Table VI

Tukey's HSD Test on Attitude Towards Biology Mean Differences

	Experimental			Control		
	Pre	Post	F. Up	Pre	Post	F. Up
Experimental						
Pre		0.04	0.05	0.39	0.78**	1.21***
Post			0.01	0.35	0.74*	1.17***
F. Up				0.34	0.73*	1.16***
Control						
Pre					0.39	0.82**
Post						0.43
F. Up						

* $p<0.05$; ** $p<0.01$; *** $p<0.001$

Table VII

Tukey's HSD Test on Attitude Towards Biochemistry Mean Differences

	Experimental			Control		
	Pre	Post	F. Up	Pre	Post	F. Up
Experimental						
Pre		0.57	0.07	0.58	0.70	0.51
Post			0.64	1.15**	1.27***	1.08**
F. Up				0.51	0.63	0.44
Control						
Pre					0.12	0.07
Post						0.19
F. Up						

* p<0.05; **p <0.01; *** p<0.001